

thickness between the cross-sectional center points of 'mutually adjacent parts (of heat generation bodies)' as shown in Figs. 1A-1B and Fig. 10(f).

Page 7, line 23 - page 8, line 19:

In this case, as according to claim 8, the maximum amount of offset of the locations may be preferably in the range of 5 to 2000 μm . The maximum amount of offset less than 5 μm may be insufficient to have the effect of offset, while the amount more than 2000 μm may arise another problem of uniformity of thermal distribution on the surface of the ceramic substrate. Here the 'maximum amount of offset' in case of spiral form, may be defined as the distance between the lowest level and the highest level of the center points in the direction of thickness of the ceramic substrate, which center points may be determined by treating the cross-section as a circle or a oval to define as the distance between the lowest level and the highest level of the center points in the direction of thickness of the ceramic substrate (see Fig. 9F), however if the spiral form is considered to be a continuity of circles having the same diameter of cross-section, or to be a continuity of ovals having the same diameter in shorter axis as in longer axis, the maximum value may be defined as the amount of offset at the top or bottom edge of the spiral. Also it should be noted that the amount of offset between 'mutually adjacent parts (of heat generation body)' may be defined as the distance between the center points of the mutually adjacent heat generation bodies.

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Figs. 1A-1B are cross-sectional side elevation views showing primary parts of a ceramic substrate of a ceramic heater in accordance with an embodiment of the present invention;

Fig. 2 is a cross-sectional side elevation view showing primary parts of a ceramic substrate of a ceramic heater in accordance with an embodiment of the present invention;

Fig. 3 is a cross-sectional side elevation view showing primary parts of a ceramic substrate of a ceramic heater in accordance with an embodiment of the present invention;

Fig. 4 is a cross-sectional plan view showing primary parts of a ceramic substrate of a ceramic heater in accordance with an embodiment of the present invention;

Figs. 5A and 5B show schematic diagrams of processes for obtaining the positional offset of heat generation bodies in a ceramic substrate of a ceramic heater in accordance with an embodiment of the present invention;

Figs. 6A to 6C are schematic plan views showing the disposition of paste layers in a ceramic substrate of a ceramic heater in accordance with an embodiment of the present invention, in the order of lamination;

Figs. 7A to 7D show schematic diagrams of processes indicating the disposition of paste layers in a ceramic substrate of a ceramic heater in accordance with an embodiment of the present invention, in the order of lamination, and Fig. 7(d) shows a cross-sectional side elevation view after the lamination thereof.

Figs. 8A-8D show flow diagrams of production of ceramic substrate in accordance with an embodiment of the present invention;

Figs. 9A-9F show flow diagrams of production of ceramic substrate in accordance with another embodiment of the present invention;

Fig. 10 shows a schematic diagram of electrodes for an electrostatic chuck in accordance with an exemplary application of the present invention;

Figs. 11A-11D show flow diagrams of production of wafer probe in accordance with an exemplary application of the present invention;

Fig. 12 is a graph showing the results of a bending resistance test after a thermal shock test; and

Fig. 13 is a cross-sectional side elevation view showing the primary parts of a conventional ceramic substrate.

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In Figs. 1A to 3, there are shown cross-sectional elevation views of a ceramic substrate 12 of a ceramic heater 10 in accordance with the present invention, which are cross-sectional side elevation views in which the ceramic substrate 12 is cut in the direction of thickness t , in a plane perpendicular to the longitudinal axis of heat generation bodies 14, 16, 18 and 20, which are in the form of ribbons with a width. Fig. 4 depicts in a schematic manner the planar conductor patterns of the heat generation bodies 14, 16, 18 and 20, by showing a cross-sectional plan view of a horizontal plane including the upper surface of the heat generation bodies 14, 16, 18 and 20 (i.e., Pla, Pla' in Fig. 1A; P2b P2b' in Fig. 2; P3b P3b' in Fig. 3, and the like).

The cross-sectional side elevation views of Figs. 1A, 1B and 2 are arranged such that the cross-section of the heat generation bodies 14 and 16 are appeared at eight locations, while the cross-sectional side elevation view of Fig. 3 is arranged such that the cross-section of the heat generation bodies 18 and 20 are appeared at sixteen locations, however such arrangement is by way of example, for the purpose of description only. The number of disposed bodies is therefore arbitrary. In addition, as shown in Fig. 4, when referring to all of the heat generation bodies 14, 16, 18 and 20, these bodies will be designated to 'heat generation body H'. Also in the figure, the reference numeral 22 designates to a terminal section of heat generation body H, and the reference numeral 24 to an insertion hole for support pins for supporting a semiconductor wafer. The heat generation body H in the proximity of the insertion hole 24 is disposed so as to pass around the insertion hole 24.

Page 13, line 15 - page 14, line 11:

The heat generation body 14 shown in Figs. 1A-1B are comprised of a heat generation body 14a and heat generation body 14b, which are disposed at mutually adjacent position, and each of heat generation bodies 14 is disposed so as to be coaxial in plan view (see Fig. 4) in the planes Pla and Plb within the ceramic substrate 12. The level of plane Pla and that of Plb are mutually offset at the amount of offset δt in the direction of thickness t . That is, the ceramic heater 10 is arranged in the direction of thickness t of the ceramic substrate 12 such that the amount of offset of the mutually adjoining heat generation bodies H may be in the range of 1 to 100 μm . This arrangement may allow the effect of thermal shock to be buffered more finely in the direction of thickness of ceramic substrate. The heat generation bodies H are arranged so as to have 5 to 50 μm of thickness. In this arrangement the expansion or shrinkage of the heat generation bodies H at the time of heating or cooling of ceramic substrate 12 may be occurred in the plane Pla and plane Plb, which are mutually offset each from other by an amount δt . This helps dispersion of stress. In the case where the heat generation body is in the spiral form, the heat generation means may preferably have an amount of offset in the mutually adjoining spiral section in the range of 1 to 500 μm .

Page 15, lines 12-25:

In the case where the heat generation body 16 is arranged as shown in Fig. 2, then for the heat conducting to the entire ceramic substrate 12, the distance from the heating surface to the heat generation body 16c and 16d may differ from the distance to the heat generation body 16a and 16b, that is, the heat generation body nearer to the outer circumference may be disposed nearer to the heating plane. This allows the temperature around the outward periphery to be prevented from decreasing. On the contrary, in the case where the heat generation bodies 16 are arranged to be convex to upper side (see Figs. 8A-8D), then inwardly disposed bodies may be nearer to the heating plane so that the decrease of

temperature in such inward section may be prevented even if the electrodes are connected beneath the inward heat generation bodies.

Page 17, lines 3-25:

As can be seen from the foregoing discussion, in accordance with the arrangement shown in Figs. 1A-1B through Fig. 3, the heat generation bodies 14, 16, 18 and 20 may be located such that at least some of heat generation bodies H are offset from others in terms of the direction of thickness t of the ceramic substrate 12. In this arrangement when heating or cooling the ceramic substrate 12, the expansion or shrinkage of the heat generation bodies H may be occurred on the planes that are mutually set off each other by the amount of offset δt , or on the planes that are mutually offset each other by the amount of offset δt and that the maximum amount of offset between farthest planes is δt_{\max} . Thus the ceramic heater 10 may be able to disperse the effect of thermal shocks into the direction of thickness t of the ceramic substrate 12 while at the same time able to maintain the uniformity of heating over the entire ceramic substrate 12.

The configuration of the ceramic heater 10 may not be limited to the above-mentioned embodiment. For example, the ceramic heater 10 may be arranged such that some of heat generation bodies H is displaced along with the longitudinal axis of the heat generation bodies H, on the horizontal level (see Figs. 7A-7D).

Page 18, line 5 - page 19, line 25:

Referring to Figs. 5A-5B, there is shown a schematic diagram illustrating a method of producing a ceramic heater, in which a heat generation body H_a is disposed offset from another heat generation body H_b . The arrangement shown in this figure is prior to baking.

As shown in Fig. 5A, by making use of a conventional process of the green sheet production method, on a lower green sheet 26c beneath the heat generation body H_b or above the heat generation body H_a , in the size capable to cover the heat generation body H_a , a paste

layer 28b and 28a are formed, by applying and drying paste containing powdered aluminum nitride (also referred to as 'paste' hereinbelow).

Then, as shown in Fig. 5B, on the upper side of green sheets 26a through 26c, a predetermined plurality of green sheets 26x, 26x+1, . . . (only two of them are illustrated in the figure) are superposed thereon which may constitute part of ceramic substrate, and under the lower side, a predetermined plurality of green sheets 26y, 26y+1, . . . (only two of them are illustrated) are superposed thereon to laminate and to pressurize together. In this manner a laminated green sheet body 30 can be obtained in which the heat generation bodies H_a and H_b are offset one from another.

Although the layer formed by using some paste as described above is described as a paste layer, because of the method of production thereof, the applied layer is not in form of paste after drying, rather in the form of film. Also in Fig. 5B, the paste layers 28a and 28b are shown by dotted lines since these layers may be integrated into the lamination structure of the laminated green sheet body 30 because the step height of the thickness of layers is absorbed. It will be further described about the paste below.

When providing a paste layer above or beneath a heat generation body, the paste layer may be formed in direct contact with the heat generation body, or the paste layer may be provided by appropriately interposing one or a plurality of green sheets therebetween. However, it should be noted that when providing a paste layer just beneath a heat generation body, the order of forming a heat generation body and a paste layer has to be reversed because the paste layer should be applied onto the surface of a green sheet at first. In other words, according to Fig. 5A, a paste layer 28b would be interposed between the heat generation body H_b and the green sheet 26b.

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Next, the process of applying paste layers and the process of laminating and pressurizing will be described below. Referring to Figs. 6A-6C, there is shown a plan view showing primary layers when laminating green sheets in the order of (a) to (c) from the topmost layer. Fig. 6A shows only a paste layer configured according to the arranging pattern. This patterned layer 28a will be superposed on the heat generation body Ha shown in Fig. 6B.

The heat generation bodies Ha and Hb are schematically illustrated on Fig. 6B on the same plane (the drawing plane). Here, the heat generation bodies are designated to Ha and Hb because, after laminating and pressurizing, the heat generation body Ha will be displaced to lower side, the heat generation body Hb will be displaced to upper side.

In the process of forming paste layers, heat generation bodies Ha and Hb will be formed on a green sheet 26b, in accordance with the pattern shown in Fig. 6B. Then, a paste layer 28a will be formed, in accordance with the pattern shown in Fig. 6A, over the heat generation bodies Ha (see Fig. 6B), which is made by applying paste containing powdered aluminum nitride thereto and by drying. Thereafter, another paste layer 28b will be formed on the green sheet 26c in accordance with the pattern shown in Fig. 6C. The paste layers may preferably have a sufficient surface area to cover the heat generation bodies.

In other words, with respect to the position of formed heat generation bodies Ha (see Fig. 6B), the paste containing powdered aluminum nitride will be applied and dried on areas on another green sheet just above (reference numeral 28a of Fig. 6A), or on areas on still another green sheet beneath (reference numeral 28b of Fig. 6C) the position of heat generation bodies when laminating and pressurizing green sheets to form paste layers. When applying paste layers, the thickness may be adjusted by repeating applying and drying (i.e., applying for many times), and the offset δt may be modified.

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The lamination and bonding process will be described below in greater details. In the order from the topmost to the bottom, (1) a desired number of plurality of plain green sheets (not shown), (2) a green sheet 26b described as Fig. 6B above with the paste layer 28a formed in accordance with the pattern Fig. 6A just above the heat generation bodies Ha, (3) green sheets 61c of Fig. 6C at lower side, and (4) a desired number of plurality of plain green sheets (not shown) are compiled so as to sandwich the green sheet 26b subject to form heat generation bodies Ha and Hb shown in Fig. 6B.

Thereafter, each of patterns shown in Fig. 6A to C will be compiled as have been described above. In other words, under the condition of interposing the paste layers between a plurality of green sheets, the entire layers will be laminated and pressurized in the direction of thickness to be bonded together.

Page 27, lines 11-23:

Referring to Figs. 7A-7D, a configuration with some of heat generation bodies being produced in positions offset along with the longitudinal axis of the heat generation bodies in a plane will be described below in greater details. With respect to the green sheet 32b with heat generation bodies H, in the upper surface thereof, a paste layer 34k will be formed over the heat generation bodies H in accordance with the pattern 34k; in the lower surface, a paste layer 34h will be formed on a green sheet 32c. Then, as similar to the case shown in Fig. 5B, other green sheets will be superposed thereon to produce the green sheet laminated body 32 as shown in Fig. 7D. The pattern 34k and the pattern of heat generation bodies H are preferably coaxial.

Page 31, line 5 - page 33, line 2:

Another embodiment of the present invention will be described below. In this embodiment, green sheet lamination is similar to the preceding embodiment, except for a mold 36 used, which has a convex or concave surface, as shown in Fig. 8. Furthermore, a

ceramic heater may be produced by adding additional five to fifty green sheets attached to both upper and lower sides, then sintering the green body under a high pressure and high temperature condition (see Fig. 8A and B) to once produce a curved ceramic substrate 40, then flattening both the upper and bottom surface by trimming (see Fig. 8C). The amount of bending in the convex or concave surface may be preferably in the range of 3 to 500 μm in order to assure the maximum amount of offset δ_{max} . The trimming amount may be preferably in the range of 5 to 1000 μm , in order to assure the flatness.

In Figs. 8A-8D, through holes 42 are provided for heat generation bodies H, and terminals 44 made of cobalt or stainless steel are attached thereto (see Fig. 8D). The temperature will be decreased around the center portion due to the heat dissipation by conduction through the terminals 44. While configuration shown in Figs. 8A-8D is unlikely to decrease the temperature because the heat generation bodies H close to the center portion are located nearer the heating plane.

Now still another embodiment will be described with reference to Figs. 9A-9F. Fig. 9A and B show a plan view and cross-sectional side elevation view indicating the arrangement of heat generation bodies H; Fig. 9C to E show flow diagrams indicating process of arranging heat generation bodies H. As shown in these figures, a green body 46 may be produced at first, then a groove 48 may be provided on the surface of the green body 46 (see Fig. 9C). The groove 48 may be formed by spot facing, or may be formed in the green sheet in advance. The width and depth of groove may be adjusted to the width and thickness of the (spiral) heat generation bodies H, respectively. More specifically, the width of spiral coil is 1 to 10 mm, thickness 0.1 to 2 mm, the groove should accept this coil. The aspect ratio (width/thickness) of cross-section of the coil is preferably 1 through 10 so as to assure the uniform temperature distribution over the entire wafer-heating surface. The location of heat generation bodies may be offset by changing the depth of adjacent grooves before assembly.

Then after fitting the heat generation bodies H into the groove 48 (see Fig. 9D) and providing powdered ceramics a thereto so as to cover the heat generation bodies, the green body will be sintered under a high temperature and high pressure of 1600 to 2000°C, 9.8 to 49 MPa·s, 100 to 500 kgf/cm² (see Fig. 9E).

Page 34, line 24 - page 35, line 3:

For this example (inventive product), the pattern shown in Figs. 1A-1B or the pattern shown in Fig. 2 was used for the arrangement pattern of heat generation bodies and paste layers.

Page 36, lines 16 - page 37, line 5:

(4) A green sheet having heat generation body pattern and conductive paste printed thereon and 30 sheets of intact green sheets were fit into a fixture having a convex plane of 500 μ m height as shown in Figs. 8A-8D. This green sheet laminated body was degreased at approximately 600°C for five hours under a nitrogen environment, hot-pressed at approximately 1890°C, pressure 14.7 MPa·s (150 kg/cm²) for three hours to obtain a ceramic substrate in the form of aluminum nitride plate with thickness of 6.0 mm. The resulting ceramic substrate was trimmed on both side by 1 mm to flatten the surface at the level of flatness of 3 μ m. The trimmed ceramic substrate was cut to a disk of diameter of 210 mm, then the opposite side of the wafer heating surface was polished to provide recesses of depth 1 millimeter. Power supply terminals were attached to the through holes exposed in the recesses, and connected to a casing.

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(3) As shown in Fig. 11A, the green sheet 56 and ceramic substrate 58 were laminated, hot-pressed at a temperature of approximately 1890°C, a pressure of 150 kg/cm² for three hours to obtain the ceramic substrate 58 incorporating guard electrodes 60 and ground electrodes 62 therein.